

# Wastewater reclamation and reuse

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Because various terms related to wastewater reclamation and reuse have not been used consistently, it may be appropriate to set forth the following definitions in this review. "Wastewater reclamation" is the treatment or processing of wastewater to make it reusable, and "water reuse" is the use of this water for a variety of applications. In addition, water reuse implies the existence of a pipe or other conveyance facilities, including pumping for delivering the reclaimed water.

"Indirect reuse," through discharge of an effluent to a receiving waterbody for assimilation and withdrawal downstream, is recognized to be important but usually does not constitute "planned reuse." In contrast to "reuse," the term "wastewater recycling" normally involves only one use or user, and the effluent from the user is captured and redirected back into that use scheme. In this context, water recycling is predominantly practiced in industry, such as in steam electric, manufacturing, and mineral industries.

This review continues the Literature Review reorganization instituted in 1984. Several topics that may be considered as wastewater reclamation and reuse will appear in other review sections in this issue. Specifically, references on agricultural and landscape irrigation are covered in the review on "Land Application of Wastewater." Wastewater treatment techniques commonly used in wastewater reclamation and reuse can be found in the various treatment sections in this issue. All industrial water recycling and reuse references have been covered in the appropriate industrial waste review. Exceptions are reuse applications for multiple industries or for miscellaneous industries not explicitly included in the industrial waste reviews. Also included in this review is the topic of water reuse for groundwater recharge. Finally, references relating to health effects appear in the review on "Health Effects Associated with Wastewater Treatment, Disposal and Reuse."

## GENERAL

The major addition in 1986 to the literature on wastewater reclamation and reuse was the proceedings<sup>1</sup> from the Second International Gothenburg Symposium held in Berlin, Federal Republic of Germany. It contained 33 papers covering chemical treatment technology, recycling of water, sludge, and treatment chemicals. Freshwater Foundation<sup>2</sup> published a special issue journal on water reuse that contained 15 articles on various aspects of wastewater reuse. The World Health Organization report<sup>3</sup> discussed industrial wastewater treatment and discharge in the Mediterranean area including recycling and reuse options.

White<sup>4</sup> published the second edition of "Handbook of Chlorination" which also included chapters on chlorine dioxide, ozone, bromine, iodine, and UV radiation. A brief historical background of wastewater reuse was included in this volume.

Culp/Wesner/Culp<sup>5</sup> published "Handbook of Public Water Systems" which contained a chapter discussing wastewater in water supply sources as well as many related topics. "Developing World Water"<sup>6</sup> covered a number of water related topics such as the United Nations Drinking Water Supply and Sanitation Decade, which emphasized water problems of the developing countries. Several other notable contributions to the subjects included, "Scarce Water and Institutional Change" by Frederick,<sup>7</sup> "The Economic Value of Water" by Gibbons,<sup>8</sup> and "Hazardous Waste Regulation—The New Era" by Fortuna and Lennett.<sup>9</sup>

## WATER REUSE PLANNING

An economical, continuous supply of irrigation water to golf courses, parks, and greenbelt areas was provided as a result of a project undertaken by two rapidly developing districts in southern California.<sup>10</sup> The city of Palm Springs, Calif., percolated its secondary effluent through alluvial natural sand layers before it was intermixed with waters in the underlying aquifer in Coachella Basin area and its tertiary effluent was used for irrigation for the municipal greenbelt area.<sup>11</sup>

On-site wastewater reclamation and reuse systems were reviewed with special reference to applications in commercial buildings and apartment complexes.<sup>12</sup> Park *et al.*<sup>13</sup> reported on water reuse projects in Korea including wastewater treatment and reuse in buildings.

## MUNICIPAL WASTEWATER REUSE

Neis *et al.*<sup>14</sup> examined the reuse of municipal wastewater in Cairo, Egypt, after treatment by a rotating biological contactor under high organic loadings. A pilot-scale reverse osmosis unit treating secondary effluent was tested in Port Elizabeth, South Africa.<sup>15</sup> Project APRICOT<sup>16</sup> in Altamonte Springs, Fla., was reviewed and several reuse plans were presented. To solve water pollution problems of the Yodo River in Japan,<sup>17</sup> five alternative plans including water conservation and recycling were discussed. A biological wastewater treatment process with powdered activated carbon was discussed with reference to water reuse.<sup>18</sup>

Removal effectiveness of enteric viruses, coliforms, and roundworm eggs in tertiary filter was examined.<sup>19</sup> Disinfection for potable reuse was carried out in Denver, Colo., using bacterial indicators and coliphage.<sup>20</sup>

A mathematical model aimed at regional optimization was described in relation to plant capacity, treatment level, and allocation of the effluent to irrigating farms.<sup>21</sup> A wastewater reclamation and reuse program at Napa, Calif.,<sup>22</sup> was required to mitigate the costs of treatment and to comply with the prohibition of summer discharge.

## GROUNDWATER RECHARGE

The following groundwater books published in 1986 contained chapters on groundwater recharge, quality, pollution control, and monitoring: "Groundwater and Wells" by Driscoll,<sup>23</sup> "Evaluation of Pesticides in Ground Water" by Garner *et al.*,<sup>24</sup> and "Vadose Zone Modeling of Organic Pollutants" by Hern and Melancon.<sup>25</sup> A quarterly *Journal of Contaminant Hydrology*<sup>26</sup> was inaugurated. The primary purpose of this journal was to publish articles on the contamination of groundwater and the behavior of organic and inorganic contaminants in both the unsaturated and the saturated zones.



Advanced wastewater treatment for groundwater recharge was used at the Berlin Water Works and Berlin Sewage Works in the Federal Republic of Germany.<sup>27</sup> Arizona's groundwater code<sup>28</sup> and groundwater recharge<sup>29</sup> were discussed.

## INDUSTRIAL WATER RECYCLING AND REUSE

Bridle<sup>30</sup> examined hot lime softening of petroleum processing effluent and recycling. A 3-year laboratory study<sup>31</sup> was conducted with pulp and paper mill wastes. Crops such as maize, barley, and wheat were grown successfully despite increases in the soil's level of exchangeable sodium. The effects of water reuse/recycling on food processing waste<sup>32</sup> were investigated with by-product recovery for animal feed production. Treatment and reuse of a complex industrial wastewater were discussed<sup>33</sup> using a combined ultrafiltration and carbon adsorption system.

Zero-discharge systems were used in commercial plating plants<sup>34</sup> and by closed loop desalination of treated wastewater.<sup>35</sup> Survey results on electroplating industry in Southeast Asia<sup>36</sup> and implementation of integrated wastes treatment<sup>37</sup> were reported. The potential for wastewater reuse and recycling by steam electric generating industry was assessed and 53 power plants using reuse/recycle measures were identified.<sup>38</sup> Complete effluent recycling in a bleach plant with ultrafiltration and reverse osmosis was reported.<sup>39</sup> Water management schemes for reducing the volume of intake water in industries were suggested which included water recycling and reuse.<sup>40</sup>

## TECHNOLOGY DEVELOPMENT

"Reverse Osmosis Treatment of Drinking Water" by Eisenberg and Middlebrooks,<sup>41</sup> contained several chapters relevant to wastewater reclamation and reuse. Disinfection of wastewater in conjunction with lime treatment, reverse osmosis, and chlorine dioxide was discussed by Rogers and Lauer.<sup>20</sup>

Tertiary treatment with ferrate coagulation and ozonation was investigated in water reuse.<sup>42</sup> Determinations of chlorine dioxide, chlorate, and chlorite in reclaimed water were discussed.<sup>43</sup> A field laundry wastewater recycling system using powdered activated carbon, polyelectrolyte, and diatomaceous earth filter was evaluated in military field laundry operations.<sup>44</sup>

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